(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
1 March 2001 (01.03.2001)

PCT

(10) International Publication Number
WO 01/15403 A1

(51) International Patent Classification[7]: H04L 27/26

(21) International Application Number: PCT/US00/05255

(22) International Filing Date: 1 March 2000 (01.03.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/378,831 23 August 1999 (23.08.1999) US

(71) Applicant: ADVANCED MICRO DEVICES, INC. [US/US]: One AMD Place, Mail Stop 68, Sunnyvale, CA 94088-3453 (US).

(72) Inventor: HWANG, Chien-Meen; 5431 Ligurian Drive, San Jose, CA 95138 (US).

(74) Agent: APPERLEY, Elizabeth, A.; Advanced Micro Devices, Inc., 5204 East Ben White Boulevard, M/S 562, Austin, TX 78741 (US).

(81) Designated State *(national)*: JP.

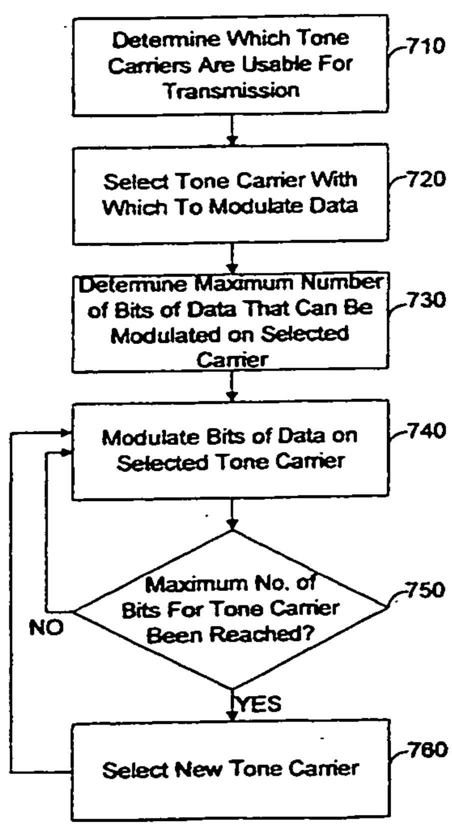
(84) Designated States *(regional)*: European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published:
— *With international search report.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: BIT ALLOCATION METHOD FOR A DISCRETE MULTITONE (DMT) SYSTEM

700



(57) Abstract: A communications system (100) includes a first and second modem (110, 105) coupled together via a communications link (115). The first and second modems (110, 105) modulate data on a plurality of tone carriers (510) for transmission therebetween over the communications link (115). The first and second modems (110, 105) determine which of the plurality of tone carriers (510) are usable for transmission and select a first tone carrier from the tone carriers (510) determined to be usable. The modems (110, 105) further determine a maximum number of bits of data that can be modulated on the first tone carrier and modulate the maximum number of bits of data on the first tone carrier.

WO 01/15403 A1

BIT ALLOCATION METHOD FOR A DISCRETE MULTITONE (DMT) SYSTEM

TECHNICAL FIELD

The present invention relates generally to modem communications, and, more particularly, to a method and apparatus for optimal data transfer in a discrete multi-tone (DMT) modem communications system.

BACKGROUND ART

The telecommunications industry has undergone explosive growth over the past several years. A significant contribution to this growth has been the high demand for modem communication services, such as the Internet, which extend beyond traditional voice communications. Conventional landline telephone networks, which offer "Plain Old Telephone Service" (POTS), currently provide these modem services by transmitting data over a voice channel. The landline telephone network reaches nearly every household and business throughout the world, and has proven to be a relatively inexpensive medium for data transmission. Although dedicated data transmission networks also exist to provide these modem services, they are considerably more expensive to use. In addition, these data networks are not readily accessible to the general public, at least compared to the accessibility of the landline telephone network. Accordingly, a substantial portion of the public relies heavily on the landline telephone network as a cheaper alternative for providing these services.

With the increasing popularity of these modem services, however, the landline telephone network has rapidly become inefficient in handling these services due to limited bandwidth constraints. Currently, the landline network's 56.6 kilobits per second (KBPS) data transfer rate is not fast enough to keep up with the increasing complexity of these services. In addition, projected demand for other services, such as video-on-demand, teleconferencing, interactive TV, etc. is likely to exacerbate the limited bandwidth problem.

To meet the demand for high-speed data communications, designers have sought innovative and cost-effective solutions that take advantage of the existing landline telephone network infrastructure. Of these solutions, the Digital Subscriber Line (DSL) technology, uses the existing landline network infrastructure of POTS for broadband communications, thus enabling an ordinary twisted pair to transmit video, television, and high-speed data.

DSL technology leaves the existing POTS service of the landline network undisturbed. Traditional analog voice band interfaces use the same frequency band (i.e., 0 - 4 kHz) for data transmission as for telephone service, thereby preventing concurrent voice and data use. Asymmetric Digital Subscriber Line (ADSL) technology, a popular version of DSL, operates at frequencies above the voice channels from 100 kHz to 1.1 MHz. Thus, a single ADSL line is capable of offering simultaneous channels for voice and data transmission. The ADSL standard is fully described in ANSI T1.413 Issue 2, entitled "Interface Between Networks and Customer Installation - Asymmetric Digital Subscriber Line (ADSL) Metallic Interface, Rev. R4, dated 6/12/98, the entire contents of which is incorporated herein by reference.

ADSL systems utilize digital signal processing (DSP) to increase throughput and signal quality through common copper telephone wire. ADSL systems provide a downstream data transfer rate from the ADSL Point-of-Presence (POP) to the subscriber location at speeds of about 6 Megabits per second (MBPS), which is more than one-hundred times faster than the conventional 56.6 KBPS transfer rate currently available through the landline network.

The technology employed in T1.413-type ADSL modems is discrete multi-tone (DMT). The standard defines 256 discrete tones, with each tone representing a carrier signal that can be modulated with a digital signal for transmitting data. The specific frequency for a given tone is 4.3125 kHz multiplied by the tone number. Tone 1 is reserved for the voice band and tones 2 – 7 are reserved for the guard bands. Data is not transmitted near the voice band to allow for simultaneous voice and data transmission on a single line. Thus, the guard bands aid in isolating the voice band from the ADSL data bands. Typically, a splitter may be used to isolate any voice band signal from the data tones. Tones 8 - 32 are used to transmit data upstream (i.e., from the user), and tones 33 - 256 are used to transmit data downstream (i.e., to the user). Alternatively, all of the data tones 8 - 256 may be used for downstream data transmission, and the upstream data present on tones 8 - 32 could be detected using an echo cancellation technique, as is well established in the art. Because a larger number of tones are used for downstream communication than for upstream communication, the transfer is said to be asymmetric.

ADSL technology significantly boosts the data transfer rate of the landline telephone network to levels at least commensurate with, if not exceeding, the transfer rates of present data networks. Assuming all 256 tones are free of impairments, the data transfer rate defined by the ADSL standard is about 6 MBPS downstream and 640 KBPS upstream, significantly dwarfing today's data transfer rate standard on the landline telephone network.

Although ADSL technology dramatically increases the available bandwidth to a single user, the user generally does not require all of the additional bandwidth for his or her own purposes. As a result, a substantial portion of the additional bandwidth is not utilized. As such, the unused bandwidth is essentially a wasted resource.

The present invention is directed to overcoming, or at least reducing the effects of, one or more of the problems set forth above.

DISCLOSURE OF INVENTION

In one aspect of the present invention, a method is provided for transmitting data in a communications system. The communications system includes a first and second modem coupled via a communications link, the first and second modems use a plurality of tone carriers for modulating data thereon to transmit the modulated data over the communications link. The method comprises determining which of the plurality of tone carriers are usable for transmission between the first and second modems; selecting a first tone carrier from the tone carriers determined to be usable; determining a maximum number of bits of data that can be modulated on the first tone carrier; and modulating the maximum number of bits of data on the first tone carrier.

In another aspect of the present invention, an apparatus is provided that includes a first and second modem adapted to modulate data on a plurality of tone carriers. A communications link couples the first and second modem together and transfers data therebetween. The first and second modems are further adapted to determine which of the plurality of tone carriers are usable for transmission; select a first tone carrier from the tone carriers determined to be usable; determine a maximum number of bits of data that can be modulated on the first tone carrier; and modulate the maximum number of bits of data on the first tone carrier.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention may be understood by reference to the following description taken in conjunction with the accompanying drawings, in which like reference numerals identify like elements, and in which:

Figure 1 is a block diagram of a communications system including a host and user modem in accordance with the present invention;

Figure 2 shows the host and user modems of Figure 1 installed within a central office and customer premise, respectively;

Figure 3 is a block diagram of the host and user modems of Figure 1 in accordance with one embodiment of the present invention;

Figure 4 illustrates a user installation of the user modem of Figure 1 in accordance with one embodiment of the present invention;

Figure 5 shows a plurality of tone carriers for a DMT symbol with bits of data modulated thereon;

Figure 6 shows a plurality of tone carriers for a DMT symbol with bits of data modulated thereon according to one embodiment of the present invention; and

Figure 7 shows a process for optimally transmitting data according to one embodiment of the present invention.

While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the drawings and are herein described in detail. It should be understood, however, that the description herein of specific embodiments is not intended to limit the invention to the particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

MODE(S) FOR CARRYING OUT THE INVENTION

Illustrative embodiments of the invention are described below. In the interest of clarity, not all features of an actual implementation are described in this specification. It will of course be appreciated that in the development of any such actual embodiment, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

Turning now to the drawings, and specifically referring to Figure 1, a block diagram of a communications system 100 is shown in accordance with one embodiment of the present invention. The communications system 100 includes a host modem 105 coupled to a user modem 110 via a communications link 115. In the illustrated embodiment, the communications link 115 is an ordinary twisted pair connection, as is common in present day telephone networks. However, it will be appreciated that other types of known communications links could be used in lieu of the twisted pair connection (e.g., fiber, radio, etc.), if so desired, without departing from the spirit and scope of the present invention.

In accordance with one embodiment, the host modem 105 is located in a central office (CO) 205 of a telephone service provider as shown in Figure 2. The user modem 110 is located in a customer premise (CP) 210, which could include a home, business, or the like. Typically, the host modem 105 will couple the user modem 110 to another service provider through the CO 205. If an individual at the CP 210 desires Internet service, for example, a connection is typically made between the user modem 110 and an Internet Service Provider (ISP) (not shown) via the host modem 105 at the CO 205. The modem 110 also provides the user with the capability of connecting with many other types of services in addition to Internet services.

In the illustrated embodiment, the host and user modems 105, 110 are DMT ADSL modems, where the host modem 105 generates the tones necessary for compatibility with the user modem 110. The host and user modems 105, 110 communicate with each other using a certain number of these tones for data transmission. Typically, the host modem 105 uses a larger number of tones for transmitting data (i.e., downstream tones) and

fewer tones for receiving data (i.e., upstream tones). Conversely, the user modem 110 typically uses more tones for receiving data and fewer tones for transmitting data.

Turning now to Figure 3, a simplified block diagram of the host and user modems 105, 110 is shown in accordance with one embodiment of the present invention. For clarity and ease of illustration, not all functional blocks are illustrated in detail because they are known to those of ordinary skill in the art, and are further defined in documents such as the aforementioned ANSI T1.413 Issue 2 standard. The host and user modems 105, 110 each include a transmitter 305 and a receiver 310 to respectively transmit and receive data with an "interfacing" modem (not shown). The interfacing modem could be either the host or the user modem 105, 110. The transmitter 305 includes an encoding unit 320 that receives outgoing digital data over a data-out line 325. The outgoing digital data may be received from a user device coupled to the modem 105, 110, such as a computer (not shown), which generates the data. The encoding unit 320 performs functions such as cyclic redundancy checking (CRC), scrambling, forward error correction, and interleaving according to methods well known to those of ordinary skill in the art. These methods are further disclosed in the aforementioned ANSI T1.413 Issue 2 standard.

The data in the transmitter 305 is grouped into frames with a plurality of these frames forming a superframe. The transmitter 305 further includes a modulator 330 that modulates tone carriers with the transmitted data. The modulator 330 performs tone ordering, constellation encoding, gain scaling, and inverse discrete Fourier transform (IDFT) functions to provide time domain waveform samples.. The set of time domain waveform samples corresponding to a frame of data forms a DMT symbol (not shown), which is transmitted over the communications link 115 to the interfacing modem (not shown). Typically, one DMT symbol contains approximately 500 bits of data; however, the DMT symbol could alternatively hold more or fewer than 500 bits. A cyclic prefix and buffer unit 335 inserts a cyclic prefix to the output of the modulator 330 (i.e., a portion of the output samples from the modulator 330 is replicated and appended to the existing output samples to provide an overlap and permit better symbol alignment). The cyclic prefix and buffer unit 335 also buffers the output samples prior to sending these samples to a digital-to-analog (D/A) converter and filter 340. The D/A converter and filter 340 converts the digital output samples from the cyclic prefix and buffer unit 335 to an analog waveform suitable for transmission over the communications link 115. As previously discussed, the communications link 115 typically consists of an ordinary twisted pair, thereby forming an analog phone connection between the host and user modems 105, 110. The communications link 115, however, may optionally include some other type of communications medium in lieu of the twisted pair connection.

The receiver 310 includes an analog-to-digital (A/D) converter and filter 350 that receives an analog waveform over the analog phone communications link 115, and samples the analog waveform to generate a time domain digital signal. An alignment and equalizing unit 355 performs symbol alignment and time domain equalization as is well established in the art. In time domain equalization, since the tones are at different frequencies, certain frequencies travel faster than others, and, as such, the tones may not arrive at the same time. The time domain equalization function of the alignment and equalizing unit 355 delays the faster tones to compensate for the propagation speed differences. There is a performance trade off between the frame alignment and time domain equalization functions in that a higher degree of frame alignment accuracy allows a lower degree of accuracy in time domain equalization. The cyclic prefix insertion performed by either the host or user modem 105, 110 improves symbol alignment accuracy. The alignment and equalizing unit 355 also performs gain control to increase the amplitude of the received signal.

A demodulator 360 receives the time domain samples from the alignment and equalizing unit 355 and converts the time domain data to frequency domain data to recover the tones. The demodulator 360 further includes a frequency domain equalizer to compensate for channel distortion. The demodulator 360 then performs a slicing function to determine constellation points from the constellation encoded data, a demapping function to map the identified constellation point back to bits, and a decoding function (e.g., Viterbi decoding, if trellis constellation coding is employed). The demodulator 360 also performs tone deordering to reassemble the serial bytes that were divided among the available tones. A decoding unit 365 performs forward error correction, CRC checking, and descrambling functions on the data received from the demodulator 360, also using methods well known to those of ordinary skill in the art. The reconstructed data provided by the decoding unit 365 represents the sequential binary data that was sent by the interfacing modem (not shown). The reconstructed data is provided to a data-in line 370 for sending the digital data to a device coupled to the modems 105, 110 such as a computer, for example.

The host and user modems 105, 110 illustrated in Figure 2 further include a control unit 315 for controlling the transmitter and receiver 305 and 310. Through a training procedure, the respective control units 315 of the modems 105, 110 sense and analyze which tones are clear of impairments in the telephone line. Each tone that is deemed to be clear is used to carry information between the modems 105, 110. Thus, the maximum data transfer capacity is set by the quality of the telephone communications link 115.

Turning now to Figure 4, a block diagram of a user installation 400 at the CP 210 is shown in accordance with one embodiment. The user modem 110 is coupled to one or more user devices 405, 410. In this particular embodiment, the user devices 405, 410 are personal computers (PC) available from a variety of manufacturers, such as Compaq Computer Corp., for example, which could include a desktop computer, notebook computer, or the like. Alternatively, a minicomputer or other type of computer system, which is typically used in commercial applications, could be used in lieu of the PC without departing from the spirit and scope of the present invention. Although two user devices 405, 410 are shown coupled to the modem 110 in Figure 4, any desired number of user devices 405, 410 could couple to the modem 110. Of course, the modem 110 can only provide a certain amount of bandwidth to adequately support a maximum number of user devices 405, 410.

The data transfer between the host modem 105 and the user modem 110, as previously mentioned, could have a maximum capacity of 6 MBPS for downstream transmission provided that all 256 tone carriers are free of impairments. The data that is generated from the user devices 405, 410 is modulated on a plurality of these tone carriers within a DMT symbol, and the DMT symbol is subsequently transmitted to the host modem 105.

Referring to Figure 5, a plurality of tone carriers 510 representing a DMT symbol is shown. Each tone carrier 510 is capable of being modulated with a maximum number of bits; however, usually not all of the tone carriers 510 can be modulated with the same maximum number of bits. This typically results from the quality of the communications link 115 between the host and user modems 105, 110, where the data capacity for certain tone carriers 510 may be reduced, or perhaps not usable. The manner in which the host and user modems 105, 110 determine the maximum number of bits that each tone carrier 510 can transmit is well known to those of ordinary skill in the art. Accordingly, the specifics of such determination will not be discussed herein so as to avoid unnecessarily obscuring the present invention.

Typically, the maximum number of bits of data that can be modulated onto a single tone carrier 510 within a DMT symbol is not fully realized. That is, generally the host and user modems 105, 110 will modulate an actual number of bits that is below the maximum number of bits that can be modulated onto a particular tone

carrier 510. For a particular DMT symbol, the difference between the maximum amplitude of the transmitted waveform and the average amplitude of the transmitted waveform is known as the peak-to-average ratio (PAR). The more tone carriers 510 that are used within a single DMT symbol to transmit data may indicate a higher PAR. A high PAR is undesirable for the transmission of data between the host and user modems 105, 110.

In accordance with the present invention, the data that is transmitted in a DMT symbol is "packed" onto as few tone carriers 510 as possible, thereby providing efficient use of the tone carriers 510 within the DMT symbol. Referring to Figure 6, the plurality of tone carriers 510 of Figure 5 are shown in accordance with one embodiment of the present invention. In this embodiment, the bits of data that are transmitted from the host or user modems 105, 110 are modulated onto certain tone carriers 510 such that these tone carriers 510 are modulated with data to the maximum amount they can carry. As a result, the PAR of the transmitted DMT symbols is substantially reduced, thereby providing a more efficient means for data transmission.

Turning now to Figure 7, a process 700 for optimally transmitting data between the host and user modems 105, 110 is shown. The process 700 commences at block 710 where the control unit 315 determines which of the 256 tone carriers 510 are usable for data transmission. This is accomplished by having the control unit 315 sense and analyze which tone carriers 510 are clear of impairments in the telephone communications link 115 according to methods well established in the art. Subsequent to determining which of the tone carriers 510 are usable, the process 700 proceeds to block 720, where the control unit 315 selects a particular tone carrier 510 with which to modulate the data to be transmitted. At block 730, the control unit 315 determines the maximum number of bits that can be modulated onto the selected tone carrier 510 using one of several methods that are known to those of ordinary skill in the art.

After determining the maximum number of bits for transmission on the selected carrier 510, the control unit 315 causes the modulator 330 to modulate the bits of data onto the selected tone carrier 510 at block 740. Subsequently, at block 750, it is determined whether the maximum number of bits that can be modulated on the selected tone carrier 510 (as determined from block 720) has been reached. If not, the process 700 reverts back to block 740 where the control unit 315 causes the modulator 330 to continue modulating the bits of data on the selected tone carrier. If, however, the maximum number of bits for the selected tone carrier has been reached, then the process 700 proceeds to block 760 where a new tone carrier 510 is selected. Subsequent to selecting the new tone carrier 510 at block 760, the process 700 reverts back to block 740 where the newly selected tone carrier 510 is modulated with data.

The process, as described above, ensures that the tone carriers 510 used for data transmission are utilized efficiently. As opposed to typical transmission schemes of the prior art, by modulating the maximum amount of data that a particular tone carrier can handle will substantially reduce the number of tones used from transmission.

The particular embodiments disclosed above are illustrative only, as the invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is therefore evident that the particular embodiments disclosed above may be altered or modified and all such variations are considered within the scope and spirit of the invention. Accordingly, the protection sought herein is as set forth in the claims below.

CLAIMS

1. A method for transmitting data in a communications system (100), the communications system (100) including a first and second modem (110, 105) coupled via a communications link (115), the first and second modems (110, 105) using a plurality of tone carriers (510) for modulating data thereon to transmit the modulated data over the communications link (115), the method comprising:

determining which of the plurality of tone carriers (510) are usable for transmission between the first and second modems (110, 105);

selecting a first tone carrier (510) from the tone carriers (510) determined to be usable;

determining a maximum number of bits of data that can be modulated on the first tone carrier (510); and

modulating the maximum number of bits of data on the first tone carrier (510).

2. The method of claim 1, wherein said modulating, further comprises:

determining whether the maximum number of bits of data to be modulated on the first tone carrier (510) has been reached.

3. The method of claim 2, further comprising:

continuing to modulate the bits of data on the first tone carrier (510) in response to the maximum number of bits of data not being reached.

4. An apparatus, comprising:

a first and second modem (110, 105) adapted to modulate data on a plurality of tone carriers (510); and

a communications link (115) adapted to couple the first and second modem (110, 105) together and to transfer the data therebetween;

wherein the first and second modems (110, 105) are further adapted to determine which of the plurality of tone carriers (510) are usable for transmission; select a first tone carrier (510) from the tone carriers (510) determined to be usable; determine a maximum number of bits of data that can be modulated on the first tone carrier (510); and modulate the maximum number of bits of data on the first tone carrier (510).

5. The apparatus of claim 4, wherein the first and second modems (110, 105) are further adapted to determine whether the maximum number of bits of data to be modulated on the first tone carrier (510) has been reached.

6. The apparatus of claim 5, wherein the first and second modems (110, 105) are further adapted to continue modulating the bits of data on the first tone carrier (510) in response to the maximum number of bits of data not being reached.

7. A modem (110) adapted to modulate data on a plurality of tone carriers (510), comprising:

a control unit (315) adapted to determine which of the plurality of tone carriers (510) are usable for transmission; select a first tone carrier (510) from the tone carriers (510) determined to be

usable; and determine a maximum number of bits of data that can be modulated on the first tone carrier (510); and

a modulator unit (330) adapted to modulate the maximum number of bits of data on the first tone carrier (510).

8. The modem of claim 7, wherein the control unit (315) is further adapted to determine whether the maximum number of bits of data to be modulated on the first tone carrier (510) has been reached.

9. The apparatus of claim 8, wherein the modulator unit (330) is further adapted to continue modulating the bits of data on the first tone carrier (510) in response to the maximum number of bits of data not being reached.

10. The apparatus of claim 8, wherein the control unit (315) is further adapted to select a second tone carrier (510) in response to the maximum number of bits of data being reached for the first tone carrier (510).

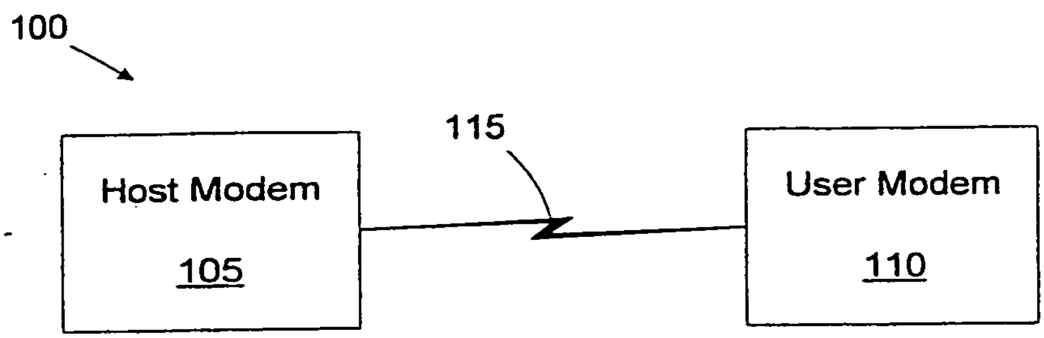


Figure 1

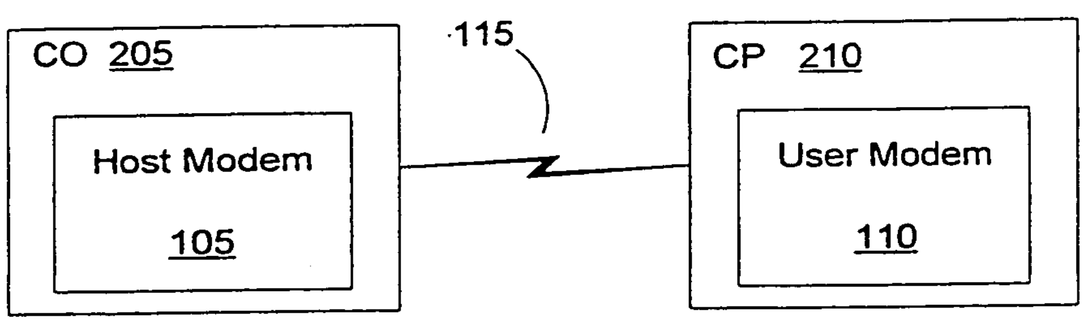
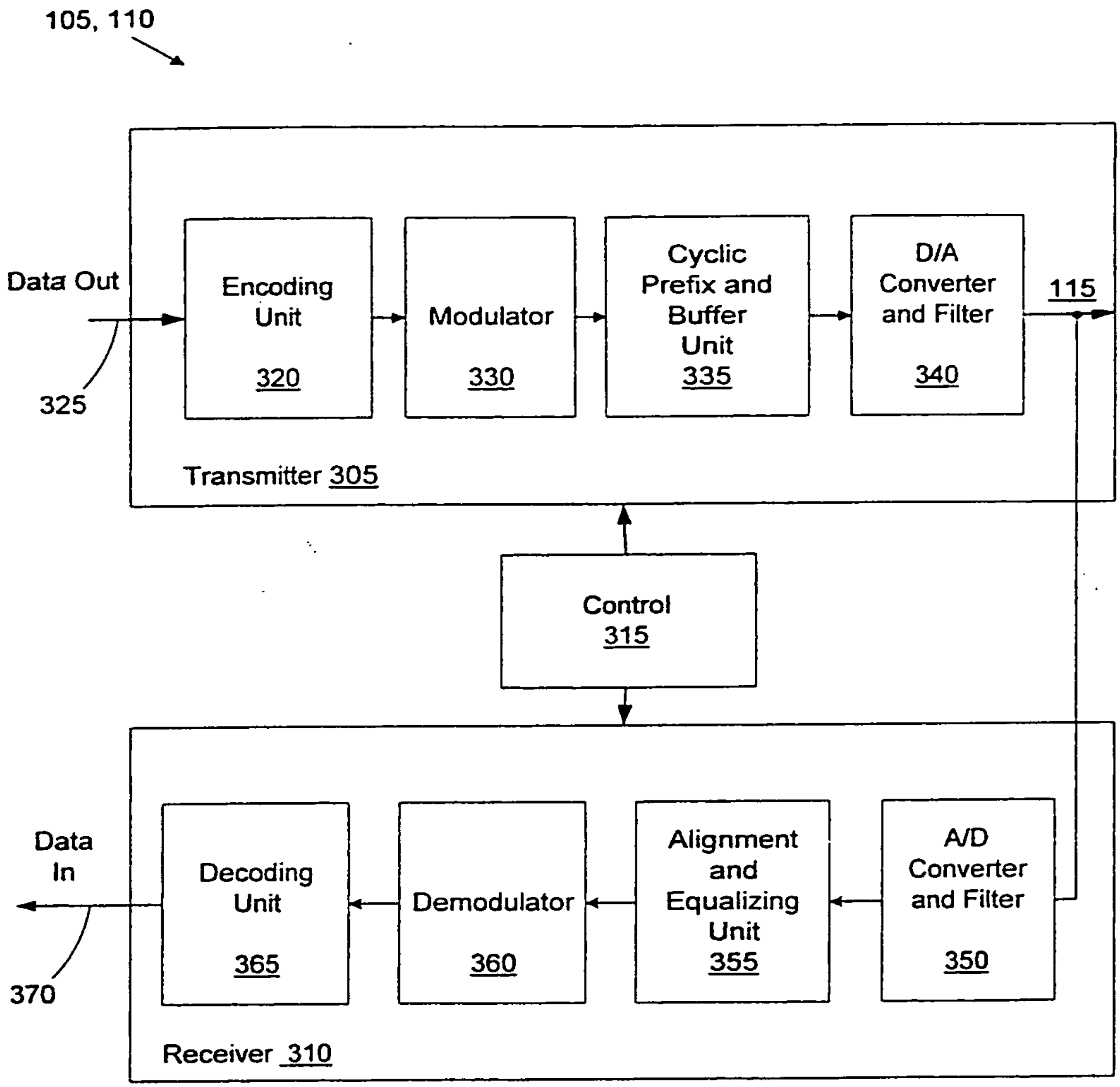


Figure 2



105, 110
Data Out
325
Encoding Unit 320
Modulator 330
Cyclic Prefix and Buffer Unit 335
D/A Converter and Filter 340
115
Transmitter 305
Control 315
Data In
370
Decoding Unit 365
Demodulator 360
Alignment and Equalizing Unit 355
A/D Converter and Filter 350
Receiver 310

Figure 3

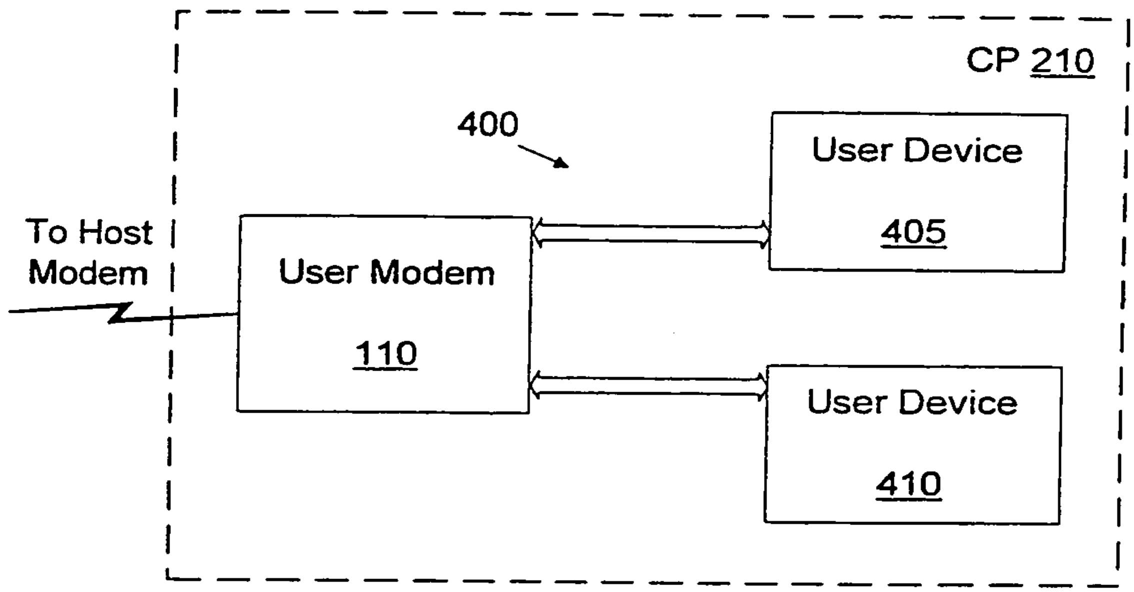

CP 210
400
User Device
405
To Host
Modem
User Modem
110
User Device
410

Figure 4

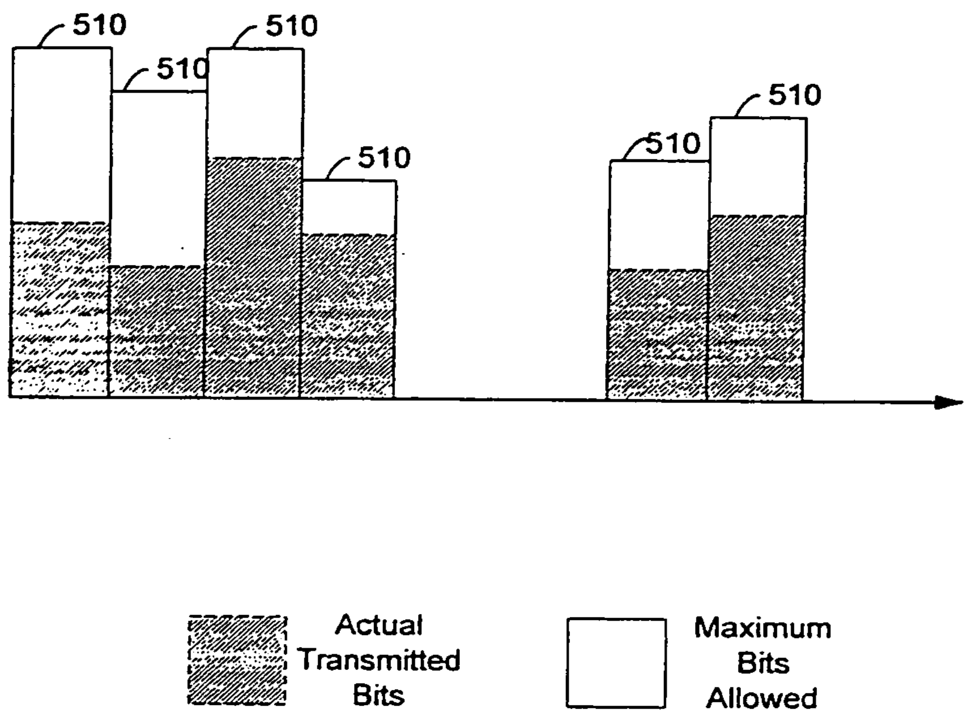

510
510
510
510
510
510
Actual Transmitted Bits
Maximum Bits Allowed

Figure 5

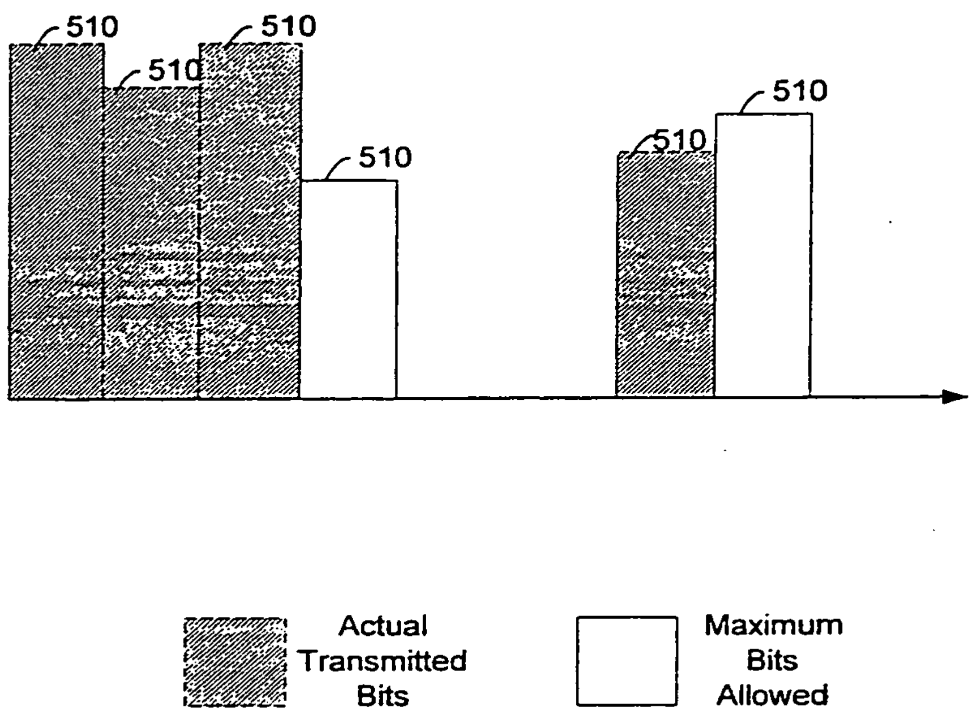

510
510
510
510
510
510
Actual Transmitted Bits
Maximum Bits Allowed

Figure 6

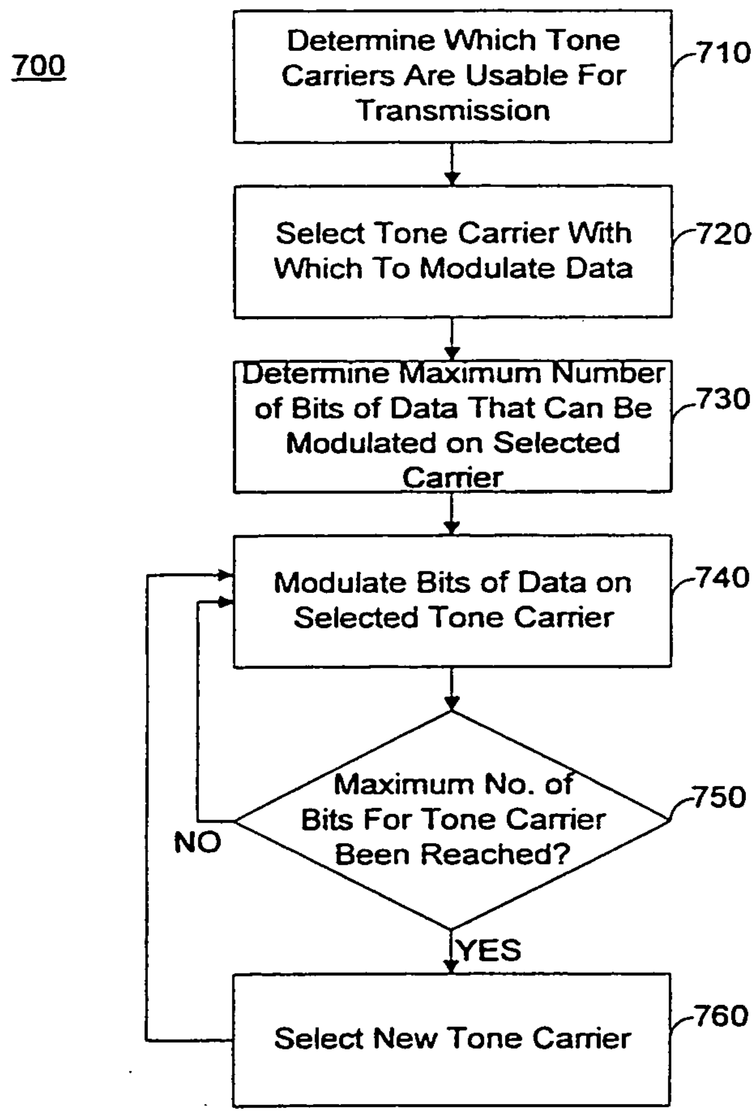

700
Determine Which Tone Carriers Are Usable For Transmission
710
Select Tone Carrier With Which To Modulate Data
720
Determine Maximum Number of Bits of Data That Can Be Modulated on Selected Carrier
730
Modulate Bits of Data on Selected Tone Carrier
740
Maximum No. of Bits For Tone Carrier Been Reached?
750
NO
YES
Select New Tone Carrier
760

Figure 7

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/05255

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04L27/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ, INSPEC, COMPENDEX, IBM-TDB

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 753 947 A (ALCATEL BELL NV) 15 January 1997 (1997-01-15) abstract column 9, line 3 -column 10, line 32	1-10
X	US 5 495 483 A (PENDLETON MATTHEW A ET AL) 27 February 1996 (1996-02-27) abstract column 30, line 43 -column 32, line 13 column 32, line 46 -column 34, line 52 claims 11,12	1-10
X	EP 0 930 752 A (MOTOROLA INC) 21 July 1999 (1999-07-21) abstract column 3, line 28 -column 4, line 10	1-10

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 June 2000	21/06/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Koukourlis, S

1

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/05255

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 98 57472 A (AWARE INC) 17 December 1998 (1998-12-17) page 10, line 3 -page 11, line 26 -----	1-10

1

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 00/05255

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
EP 0753947	A	15-01-1997	AU	701040	B	21-01-1999
			AU	5832696	A	23-01-1997
			CA	2180973	A	12-01-1997
			US	5812599	A	22-09-1998
US 5495483	A	27-02-1996	NONE			
EP 0930752	A	21-07-1999	JP	11317723	A	16-11-1999
WO 9857472	A	17-12-1998	AU	7827398	A	30-12-1998